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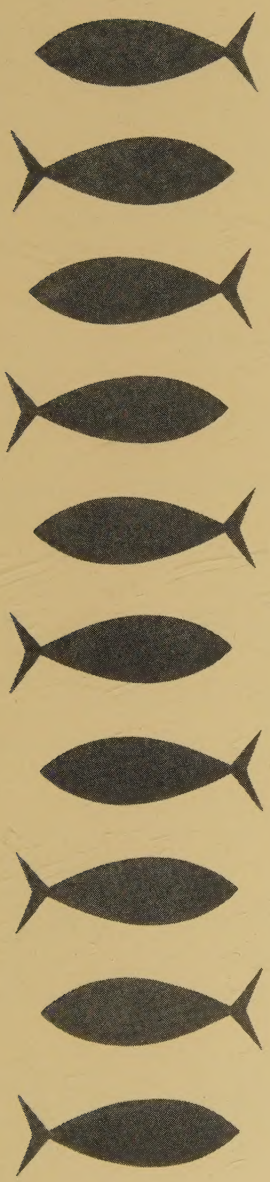
Southwest FISHERIES SCIENCE CENTER

HONOLULU LA JOLLA MONTEREY TIBURON

REPORT OF ACTIVITIES January-February 1993



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ANTARCTIC ECOSYSTEM RESEARCH GROUP

La Jolla, California

First Leg of 1993 AMLR Cruise Completed

On February 9, 1993, the NOAA Ship *Surveyor* returned to the port of Punta Arenas, Chile, completing the first portion of the U.S. Antarctic Marine Living Resources (AMLR) program's annual research cruise in the waters surrounding Elephant Island, South Shetland Islands, Antarctica. The AMLR program, which is managed by the Antarctic Ecosystem Research Group (AERG) at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, has been conducting research in this 15,000-square-mile area of the Southern Ocean for five consecutive austral summers.

The AMLR program provides information needed to formulate U.S. policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system.

The long-term objective of the AMLR field research program is to describe the functional relationships between krill (the keystone element of the Antarctic marine ecosystem), their environment, and their predators (mainly penguins and seals). The field program is based on two working hypotheses: (1) krill predators respond to changes in the availability of their food, and (2) the distribution of krill is affected by both physical and biological aspects of their habitats. In addition to studies performed during the annual cruises, land-based studies are accomplished each season at a field camp located on Seal Island, a small island off the northwest coast of Elephant Island.

This year's cruise began on January 11, 1993, when *Surveyor* departed from Punta Arenas via the eastern end of the Strait of Magellan. The ship arrived in the study area in the early hours of January 14. The first order of business was to offload fresh food provisions and other supplies to the field team on Seal Island. The weather was initially cooperative but the resupply was halted after approximately 8 hours.

On January 15, the scientific party initiated a large-area survey, consisting of a 91-station grid, covering an area of approximately 11,025 nm^2 within the AMLR study area. Krill and other zooplankton were located using a state-of-the-art acoustic survey system, which is based on echo integration technology, a relatively advanced methodology for relating total echo power to animal abundance. The system consists of 120- and 200-kHz transducers mounted in a dead weight towed body, towing and deck cables, a winch deployment system, a transceiver, a signal digitizer, software for echo integration and target strength analysis, a color monitor for initial processing and display, and a color printer. In addition, a UNIX workstation is used to manage and archive the high volume data streams captured by the system.

During the large-area survey, the acoustic system was operated continuously at a speed of 8-10 knots, only pausing when the ship was sampling at a station. Unfortunately after completion of station 32 of the 91 stations, the towed body was lost. Three retaining bolts broke and the system fell to the bottom. During the next 24 hours, Ocean Acoustics Engineer David Demer assembled a backup system. While the system was being assembled, the resupply of Seal Island was completed. The backup system worked very well during the rest of the leg but required that the ship not exceed 7 knots.

The intent of the large-area survey was to describe the thermohaline structure of the waters, phytoplankton biomass and productivity, major zooplankton constituents, and krill biomass. Operations at each station included (1) measurements of temperature, salinity, oxygen, light levels, light-beam transmission, and fluorescence; (2) collection of discrete water samples using a conductivity-temperature-depth (CTD)/rosette apparatus at standard depths for analysis of chlorophyll-a content, absorption spectra, particulate organic carbon and nitrogen content, primary production, ATP and DNA content, size fractionation, floristics, and inorganic nutrient content; and (3) deployment of a large plankton net to obtain samples of zooplankton and nekton (krill).

The 6-ft Isaacs-Kidd-Midwater-Trawl (IKMT) fitted with a 505 micron nytex plankton net, which was developed last year, was used to sample krill and other zooplankton. This net provided sufficient quantities of krill as well as representative samples of the ambient plankton assemblage.

The large-area survey was completed on January 31. A small-area acoustic survey was then con-

ducted to the north of Elephant Island February 1-3. This survey was conducted at a ship's speed of 7 knots with no CTD/rosette casts or net-sampling stations. Based on the results of the small-area survey, acoustic sampling of krill was conducted along the same tracklines during daylight hours with directed sampling using a Multiple-Opening-Closing-Net-Environmental-Sampling-System (MOCNESS) being conducted during nighttime.

On February 5, *Surveyor* again called at Seal Island to pick up two members of the field team. *Surveyor* then returned to Punta Arenas for a 3-day port call. During the port call, the ship took on supplies and received Leg II scientific personnel. The ship departed from Punta Arenas on February 14 to begin Leg II of the cruise. (J. Rosenberg, [619] 546-5600)

COASTAL FISHERIES RESOURCES DIVISION

La Jolla, California

Sablefish Fecundity Studied

Division Chief John Hunter of the Coastal Fisheries Division reports that he and Fishery Biologist Beverly Macewicz have completed a study on the potential annual fecundity of sablefish, *Anoplopoma fimbria*, from off the Oregon coast that supplements their earlier work on sablefish taken off the central California Coast. In a paper on their previous studies, they demonstrated that the potential annual fecundity was determinate; that is, it became fixed (oocytes no longer recruited into the advanced stock of yolked oocytes) when the average oocyte diameter of the advanced stock was 0.7 mm or larger. However, they noted that an inverse relationship existed between fecundity and diameter of the advanced stock in the female sablefish used to estimate annual fecundity from the central California Coast. One interpretation of this correlation is that some of the females had begun to spawn.

In the current study, Hunter and Macewicz used a large December data set (N=126 females) from Oregon to investigate sablefish fecundity. Similar to the California study, the multiple regression analysis of fecundity on female weight and oocyte diameter indicated that for Oregon females, when the mean diameter of the advanced oocytes was >1.17 mm, oocyte diameter was inversely correlated with fecundity, indicating a loss of oocytes probably caused by spawning. The total fecundity of a 2600-g female, with an advanced stock average oocyte diameter of less than 1.18 mm, was about 285,000 advanced oocytes. Whereas, fecundity of a 2600-g female, with an advanced stock average oocyte diameter larger than 1.17 mm, was 246,000. As the initial spawning batch size was about 37 oocytes per gram of body weight, the group of females with larger oocytes differed in fecundity from those with smaller oocytes by about 0.40 of a spawning batch, indicating that about a third of the females with larger oocytes may have spawned one batch. Considering all the females with active ovaries taken in Oregon during December, this means about 10 percent of them may have spawned once. This is of interest since it was generally believed that sablefish do not spawn in December off Oregon's coast.

The potential annual fecundity of sablefish from off Oregon's coast (F), considering only females with the mean diameter of their advanced oocytes smaller than 1.18 mm, is expressed by the equation F=164.1W-141550, where W is female wet weight (without ovary) and r^2=0.75 and DF=88. This equation is not statistically different from the one for central California coastal sablefish when females with mean oocyte diameters greater than 1.17 mm are deleted (F=164.0W-115501, r^2=0.59 and DF=36). Thus, annual fecundity of sablefish off California seems about the same as those from Oregon (Fig. 1), combining both data sets generates the equation F=161.2W-126654, r^2=0.73 and DF=125.

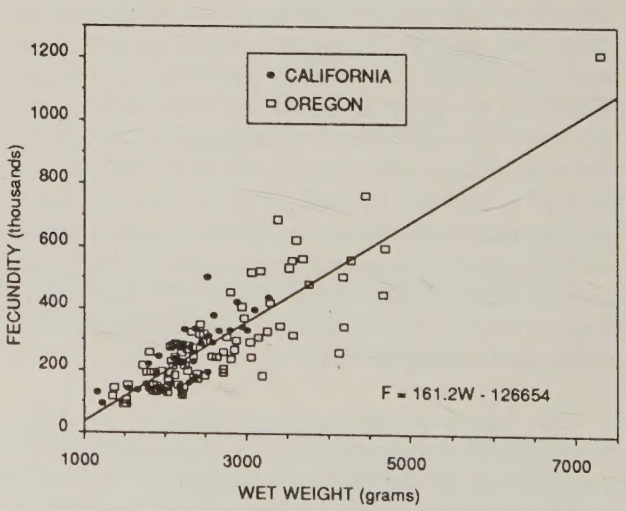

Figure 1. Potential annual fecundity (number of advanced oocytes in ovary) for female sablefish with average advanced oocyte diameters between 0.74 and 1.17 mm from off the coasts of central California and Oregon.

According to literature citing a study by Mason et al. in 1983, annual fecundity of Canadian sablefish are about half the above values. Hunter and Macewicz believe this probably is because the earlier authors did not adjust for potential losses due to spawning. Such issues were rarely, if ever, discussed at the time the Canadian paper was written and even today it is often not recognized that a very limited temporal window exists for measurement of potential annual fecundity. If one samples too early, all oocytes have not been recruited into the advanced standing stock; if one samples too late, some of the stock has been lost due to spawning.

For sablefish females, the optimal maturity window for estimating potential annual fecundity was when advanced stock mean diameters were between 0.7 mm and 1.18 mm. Similar results for Dover sole were obtained by Hunter et al. (1992). They found that the maturity window for measurement of potential annual fecundity of Dover sole was between a mean oocyte diameter of 0.85 and 1.1 mm. As Dover sole and sablefish have eggs of about the same size (roughly 2 mm in diameter), it is not surprising that the maturity window based on oocyte diameter is similar. Since fishes' egg size varies greatly, the maturity window for estimating potential annual fecundity must also vary.

This information, along with new data on atresia and batch fecundity, will be presented at a symposium on sablefish to be held in April 1993 and will be published as part of the report of that symposium. (J. R. Hunter and B. J. Macewicz [619] 546-7127 or 7107)

Pre-FORAGE Cruise Oceanography Analyzed

Oceanographer Ron Lynn reports that the initial analysis of physical oceanography for the *David Starr Jordan* March 1992 Pre-FORAGE survey is complete. This survey was conducted near the height of the 1992 El Niño, the consequences of which were evident in the current dynamics and the distribution of water properties: The California Current jet was strong and centered 260 km off Pt. Reyes (Fig. 2). The jet forms a boundary between water masses as evidenced by large lateral gradients in properties. A broad and strong countercurrent (poleward flow) was inshore of the current jet, a feature attributed to the El Niño phenomenon. Over the long term, average surface flow in the study area is toward the equator during this season. An apparent effect of the countercurrent was the formation of an additional gradient boundary delineating coastal waters (warm, saline, and low oxygen concentration) from the complex pattern of mixed waters east of the current jet. A subsurface anticyclonic eddy, found to the west of the current jet, contained in its core water properties that are identified as being of coastal undercurrent origin. This eddy was likely generated from a dynamic instability in the undercurrent about a bathymetric feature or as an interaction with a coastal loop in the current jet. It then migrated west and north. Measurement of beam transmittance showed that the entire region surveyed had very high water clarity (low productivity is characteristic of El Niño conditions). Even with these low readings of beam transmittance, there was an evident gradient roughly aligned with the California Current jet. The westward waters were the clearest.

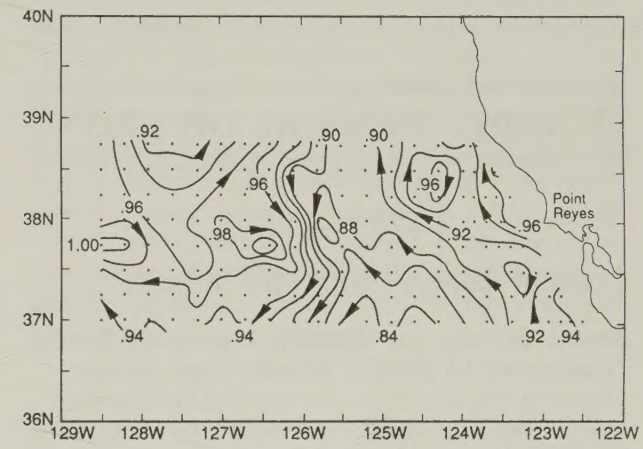

Figure 2. Dynamic height of sea surface off Pt. Reyes, near San Francisco, California (relative to 500 decibars), observed on March 19, 1992, cruise aboard *David Starr Jordan* during height of 1992 El Niño.

The next steps in this analysis are to make comparisons between these findings and earlier surveys (1991 surveys), oceanographic studies conducted by other scientists (especially the Coastal Transition Zone project), and the CalCOFI data base. The results of this analysis will be combined with the studies of larval and young juvenile groundfish (collected concurrently with the physical data) in the investigation of retention and dispersal strategies of these fish. The goal of these studies is to create a west coast groundfish recruitment model based on oceanic circulation. (R. Lynn, [619] 546-7084)

Daily Increments Validated in Dover Sole Otoliths

Biological Technician Kathy Dahlin and Fishery Biologist John Butler have validated the formation of daily increments in the otoliths of larval Dover sole, *Microstomus pacificus*. Dover sole were spawned in the La Jolla Laboratory aquarium by Fishery Biologist Eric Lynn and Biological Technician Larry Robertson. Eggs were incubated at three temperatures—5, 8, and 12 °C. After hatching, larvae were fed the rotifer *Brachionus biplicata*. Larvae were sampled periodically and preserved for analysis. Otoliths were examined using scanning electron microscopy. The microincrements in the otoliths will be used to age Dover sole larvae collected in the wild. Butler, Dahlin, and Ecological Systematics of Fishes Task Leader Geoff Moser are preparing a manuscript on the duration of the planktonic phase of Dover sole. (J. Butler, [619] 546-7149)

MARINE MAMMAL DIVISION

La Jolla, California

Coastal Marine Mammal Program

Aerial Survey for Marine Mammals Being Conducted in Pacific Missile Test Range

The Southwest Fisheries Science Center's (SWFSC) Marine Mammal Division has been contracted by the U.S. Navy, Pt. Mugu, to study the seasonal and spatial distribution of marine mammals within the Pacific Missile Test Range, west of San Nicolas Island, California. The study, an aerial survey for cetaceans and pinnipeds, will provide the Navy with information regarding marine mammal density and distribution within the Pacific Missile Test Range. The goal is to minimize the impact of Naval operations on marine mammals by identifying seasons and places within the Pacific Missile Test Range where marine mammal densities are lowest.

The study area (Fig. 1) is located south of San Miguel and Santa Rosa islands, and west of San Nicolas Island. A total of 29 transect lines are spaced 5 nautical miles apart, forming an overlapping grid of transects, totaling 2,346 kilometers (or 1,267 nautical miles). The aerial surveys, which began on January 23, 1993, utilize line transect

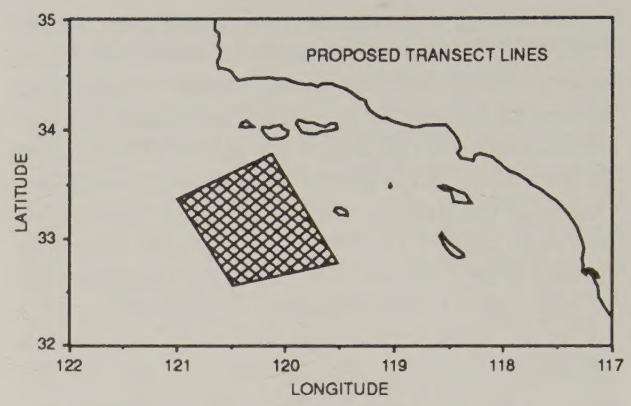

Figure 1. Aerial survey study area for marine mammals within the Pacific Missile Test Range, west of San Nicolas Island, California. The surveys began January 23, 1993. A survey grid totaling approximately 2,346 kilometers will be covered each month through the spring of 1994.

methodology, and a Partenavia Spartacus twin turbo-prop aircraft. An attempt will be made to complete an entire survey grid (2,346 km) each month, through the spring of 1994. Surveys are being conducted primarily on weekends, to avoid interference with Navy operations during the week.

Since the distribution of marine mammals is largely affected by prevailing oceanographic conditions, sea surface temperature and thermocline data will be collected on future surveys. Short-term oceanographic changes, such as transient upwelling events, eddies, and even changes in the position of the California Current are known to occur within the study area. For this reason, oceanographic data will be collected utilizing aerial expendable bathythermographs (AXBTs), which will be released from the aircraft into the water to measure the temperature profile data. The simultaneous collection of oceanographic and marine mammal sighting data will allow for a better prediction of where and when areas of low marine mammal density may occur within the study area.

As of February 19, 1993, a total of 2,601.6 kilometers (1,405 nmi) had been surveyed within the study area, with a total of 71 on-effort sightings being recorded. An additional 60 sightings have been recorded off effort, or outside the study area. Figure 2 shows the locations of the 131 sightings that have been recorded to date. Of these 131 sightings, 112 were identified as to species. A total of 10 cetacean species and 2 pinniped species have been sighted since the surveys began. These species, along with the combined number of on- and off-ef-

fort sightings recorded for each, are listed in Table 1. (J. Carretta, [619] 546-7181).

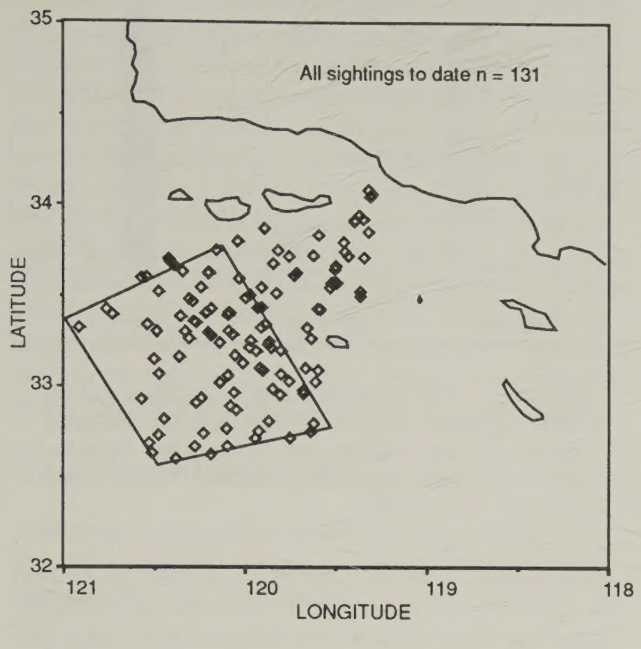

Figure 2. The 131 cetacean sightings recorded from January 23-February 19, 1993, in the marine mammal survey area of the Pacific Missile Test Range. □ = each sighting.

Table 1. Species sighted during aerial surveys for marine mammals within the Pacific Missile Test Range from January 23-February 13, 1993.

Species	Number of Sightings
Fin whale, *Balaenoptera physalus*	5
Common dolphin, *Delphinus delphis*	7
Gray whale, *Eschrichtius robustus*	12
Risso's dolphin, *Grampus griseus*	13
Northern right whale dolphin, *Lissodelphis borealis*	13
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	4
N. elephant seal, *Mirounga angustirostris*	1
Killer whale, *Orcinus orca*	4
Dall's porpoise, *Phocoenoides dalli*	1
Sperm whale, *Physeter macrocephalus*	1
California sea lion, *Zalophus californianus*	48
Cuvier's beaked whale, *Ziphius cavirostris*	3

Dolphin Ecology Program

Seabird Studies in the Eastern Tropical Pacific

Lisa Ballance, fisheries biologist, and Robert Pitman, biological technician, have been studying seabirds of the eastern tropical Pacific (ETP) since 1979 in an effort to better understand the ecosystem in which spotted and spinner dolphins live. Many seabirds are dependent on schools of predatory dolphins and associated tuna to make prey available at the surface for the birds to feed on.

One example of this kind of seabird is the booby. Boobies belong to the family Sulidae, which inhabits tropical and subtropical oceans. There are nine species worldwide, but the ETP supports the most diverse assemblage to be found anywhere: the Blue-footed, Peruvian, Masked, Red-footed, and Brown Boobies. Of these, two are found exclusively in the ETP (Blue-Footed and Peruvian), and the remaining three (Masked, Red-footed, and Brown Boobies), while occurring elsewhere, have their largest colonies on islands within the ETP. In addition, two forms of Masked Booby that breed assortatively (nonrandomly with each other) when nesting on the same ETP islands, probably represent two separate species. With such diversity and abundance, the question of how these species co-exist becomes an interesting one.

Pitman and Ballance have been studying the foraging behaviors of the three most abundant boobies (Masked, Brown and Red-footed) by observing their feeding around research vessels and in flocks over schools of tunas and dolphins. These boobies use three different foraging methods. The first and most common is typical plunge diving. Birds using this method vertically plunge into the water from heights of up to 25 meters to capture submerged prey. The second method is aerial feeding which occurs when boobies take flying fish, and sometimes flying squid, that are flying above the water. These prey are often flushed up out of the water by feeding schools of fishes and mammals and also by the ship as it moves through the water. Aerial-feeding boobies pursue a flying prey item by dropping down to just above the water surface and moving toward it steadily from directly behind, then plucking it out of the air. The third feeding method is termed "skim-plunging." Like aerial feeding, this method is used when prey are flying above the water surface, but instead of catching it in the air, the bird waits until the prey drops back into the

water before making a low-angle dive and attempting to capture it underwater.

Observations were divided into two categories: (a) boobies feeding away from the ship, either in flocks with schools of subsurface predators or solitarily, and (b) boobies associated with the research vessel, mainly chasing prey flushed up out of the water by the passing ship.

Feeding away from the ship involved both flying and submerged prey, while foraging with the vessel almost exclusively involved flying prey. Away from the ship, plunge diving was the method used most by all three species: 99 percent of the time for Masked Booby, 82 percent of the time for Brown Booby, and 68 percent of the time for Red-footed Booby (Fig. 3). However, only the Brown Booby also used skim-plunging (in 17 percent of the feeding attempts) and only the Red-footed also used aerial feeding (in 32 percent of the feeding attempts).

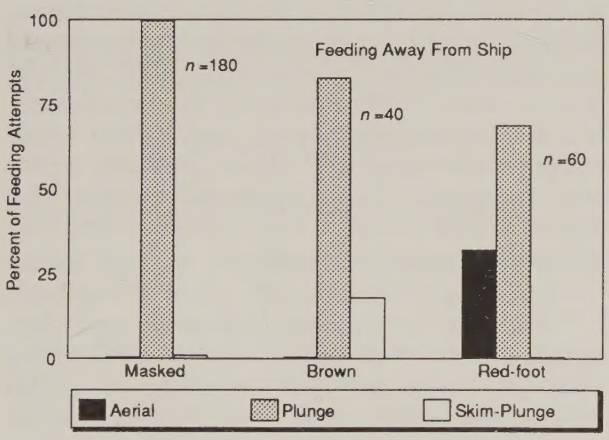

Figure 3. The three foraging methods used by eastern tropical Pacific Masked, Brown, and Red-footed Boobies observed feeding away from the vessel, including birds in flocks with schools of subsurface predators and solitarily. Data are from 1979-1990.

Foraging behaviors of boobies associated with the vessel were markedly different (Fig. 4). The Masked Booby continued to use plunge diving almost exclusively (92 percent of the time), but the Brown Booby fed primarily by skim-plunging (84 percent of the time) and the Red-footed Booby almost always fed aerially (97 percent of the time).

In general, the Redfoot was found to be the most aerial feeder of the three, especially when feeding near the vessel where available prey was almost

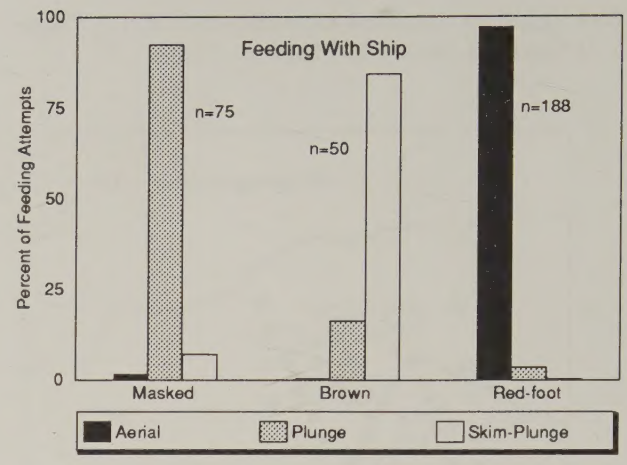

Figure 4. The three foraging methods used by Masked, Brown, and Red-footed Boobies observed feeding on prey flushed out of the water by a research vessel in the eastern tropical Pacific. Data are from 1979-1990.

exclusively airborne. The Masked and the Brown Boobies tended to be mostly plunge feeders away from the ship, with Brown Boobies also using the unique method of skim-plunging, especially when chasing aerial prey flushed out of the water near the ship.

Ballance's and Pitman's observations indicate that although there is overlap in the foraging behaviors of these three boobies, specialization does exist, which allows them to exploit different prey behaviors. In pelagic waters of the eastern tropical Pacific, Masked and Red-footed Boobies regularly occurred in the same feeding flocks, and they had the most divergent feeding methods. In contrast, the Brown Booby was more of a nearshore feeder. It fed less often with Masked and Red-footed Boobies and it seemed to be more of a generalist, utilizing all three foraging methods.

As might be expected, these different feeding methods correlate with body size differences in the three boobies. The consistent plunge diver, Masked Booby, is the largest and heaviest species with adaptations for deep plunging (heavy bill, reduced facial feathering). The aerial-feeding Red-footed Booby is the smallest, most agile species, with adaptations for aerial pursuit that include long and narrow wings and tail, and a slender bill. The generalist, Brown Booby, is intermediate in size.

In 1967, Ashmole and Ashmole in a classic study of tropical seabird feeding ecology, proposed that in closely related seabirds, different body sizes allowed similar species to take different-sized prey,

thus reducing competition. What Ballance and Pitman have seen for boobies feeding on the open ocean, based on stomach sampling and behavioral observations, is that there is almost complete overlap in the sizes and species of prey taken and that body size differences in boobies are probably more related to foraging strategy rather than to absolute prey size. Body size differences may ultimately reduce competition among feeding boobies, but not in the way the Ashmoles suggested. For example, the Red-footed Booby, being more diminutive in size, is an aerialist and is more adapted to taking disturbed (flushed) prey and may be more capable of exploiting the feeding activities of surface foraging tunas than the Masked Booby, which is larger and better equipped to take deeper, undisturbed prey. (R. Pitman and L. Ballance, [619] 546-7173).

Population Identity Program

Molecular Genetic Methods Tested for Discriminating Among Closely Related Beluga Whale Populations

Gregory O'Corry-Crowe, visiting scientist from the University College Dublin, and Andrew Dizon, task leader of the Population Identity Program, are testing the efficiency of three modern molecular techniques for determining relative genetic relatedness among local populations of the beluga whale. The goal of the study, funded jointly by the State of Alaska (North Slope Borough) and the Alaska and Southwest Fisheries Science Centers (SWFSC), is to lay the groundwork for a more comprehensive study of the beluga. Knowledge gained in the present study will assist in other mission-related stock studies of impacted marine mammals.

The three methodologies being tested are (1) direct sequencing of mitochondrial DNA (routinely used for both fish and marine mammal studies at the SWFSC), (2) genotyping of microsatellite loci, and (3) the so-called rapidly amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR). Direct sequencing will take little development effort and investigators are delaying initiation of that phase until the recently made-available automated sequencer is online. Microsatellite studies are planned but have not yet been initiated. The RAPD-PCR study, however, has already borne some exciting results. The technique is based on the enzymatic production of copies of portions of sample DNA. The reaction is "primed" by single oligomers (10 base pair long segments of DNA) of some fixed but arbitrary nucleotide sequence, the single arbitrary primers being half the size of those used for amplifying specific areas in the DNA such as in the direct sequencing approach (conventional PCR).

Two points are important in the RAPD-PCR method: (1) the smaller the primer employed, the higher the probability of its being complementary to multiple sites in the genome, and (2) the location of the primer sites within the sample's genome are unknown. For example, the probability of multiple sites existing that are complementary to a largish primer, such as ACA CCA GTC TTG TAA ACC, is very small. However, if a smaller primer is used, like ACA CCA GTC, it would likely find dozens of sites on both strands of the 10^8 bp genome and prime the DNA polymerase enzyme to produce, when used in a PCR reaction, multiple fragments–each fragment being a copy of the segment of DNA between the randomly primed sites. When the segments produced by the RAPD-PCR procedure are electrophoresed to separate them by size, the pattern produced becomes a genomic fingerprint of the sample.

When patterns are compared between individuals sampled from various taxa or geographic populations, one has a rapid way of searching for genetic markers (presence of specific fragments in the pattern) for the taxa or populations. The power of the technique stems from having the ability to utilize an almost infinite array of arbitrary primers, each producing its own array of polymorphic patterns; the chances of finding markers for the taxa or population groups if they are genetically unique at some level are thus materially enhanced.

To date, genomic DNA has been extracted from 20 beluga samples from Alaska waters in preparation for conducting the RAPD amplifications. Several experiments have been conducted to refine reaction conditions so that the yield of PCR product is high, and thus, the resolution of individual DNA patterns is good.

Lack of repeatability is the main weakness of the RAPD-PCR approach. Concern has been expressed in the literature over the sensitivity of the process to variation in collection, storage, extraction, and the PCR reaction conditions itself. The investigators are currently developing ways to standardize all of the steps to attempt to eliminate the sources of bias. They have been collaborating with a small company that is marketing a newly developed tissue preservation device called "GeneKeeper." As well as making the collection of specimens easy, the device greatly shortens the time spent extracting the DNA prior to PCR amplification, thus eliminating vari-

ability associated with those steps. By critically evaluating the various techniques that are employed at each stage of the process, from sample collection to data analysis, the investigators hope to eliminate the main pitfall of the RAPD-PCR approach, allowing its major strengths of speed and sensitivity to be utilized for studies of genetic diversity in closely related populations (A. Dizon and G. O'Corry-Crowe [619] 546-7089).

HONOLULU LABORATORY

Honolulu, Hawaii

French Researcher Visits Laboratory

Vincent Dufour, of the Laboratoire d'Ichtyocologie Tropicale et Méditerranéenne, École Pratique des Hautes Études (EPHE) at the University of Perpignan in France, spent a month at the Honolulu Laboratory working with Director George Boehlert and Fishery Biologist Bruce Mundy. Dufour has worked on larval recruitment and colonization problems in Moorea, where EPHE has a marine laboratory. His work has principally been concerned with the nearshore aspects of recruitment and colonization, an area complementary but distinct from the nearshore and mesoscale plankton sampling work relative to recruitment, which is being conducted in the Fisheries Oceanography Research Program at Johnston and Palmyra Atolls, and the large-scale recruitment research conducted by Insular Resources Investigation Chief Jeffrey Polovina on lobster stocks in the Northwestern Hawaiian Islands.

Dufour spent time in the ichthyoplankton laboratory examining specimens and working with Mundy on larval identification problems. He also discussed potential collaborative research with selected investigators at the Honolulu Laboratory. Research combining the different approaches to recruitment questions in tropical and subtropical island and reef systems would be a productive research area. (G. Boehlert, [808] 943-1211)

Townsend Cromwell Repairs Planned

Funding has been allocated by NOAA, through the Fleet Replacement and Modernization (FRAM) program, to conduct a "repair-to-extend," or RTE, for the NOAA ship *Townsend Cromwell*. The $2 million effort will allow improvements to the vessel that will allow continued operation until the year 2000, when a replacement vessel is scheduled to be commissioned. The Honolulu Laboratory staff has discussed a variety of ideas for repairs and improvements, including longstanding requests for replacement of items such as the stern crane and trawl winches. Several other modifications, including modernizing the wet lab, new instrumentation, and improved operational characteristics, were discussed in the meetings.

Laboratory Director George Boehlert attended two meetings at the Pacific Marine Center (PMC) in Seattle to discuss specifics of the RTE. A committee consisting of Boehlert and representatives of FRAM, PMC, and the vessel has developed priorities within different categories. A draft document describing the deliberations, with priority listings, descriptions of the work to be done, and rough cost estimates, should be completed in March 1993. A time schedule for final documentation, approval, bid specifications, and the final job has been developed, and the work will likely be initiated in calendar year 1994. (G. Boehlert, [808] 943-1211)

PROTECTED SPECIES INVESTIGATION

Hawaiian Monk Seal Recovery Team Meets

The Hawaiian Monk Seal Recovery Team met January 4-5, 1993, at the National Marine Mammal Laboratory, Alaska Fisheries Science Center. Team members present were Douglas DeMaster (chair), leader of Seattle's National Marine Mammal Laboratory's (NMML) Arctic Ecosystem and High Seas Drift/Gillnet Programs; Robert Brownell, U. S. Fish and Wildlife Service (USFWS); Robert DeLong, leader of NMML's California Current Ecosystem Program; Lee Eberhardt, previously with Batelle Industries; William Gilmartin, chief of Honolulu Laboratory's Protected Species Investigation; Ancel Johnson, previously with USFWS; and Ian Stirling, Canadian Wildlife Service. Also attending was La Jolla Laboratory Senior Scientist William Perrin, representing the Marine Mammal Commission.

The Team reviewed the current status and trends of the five major breeding populations and Midway, based on data collected in 1992; the results of a pilot depth-of-dive satellite tracking study; the emaciated seal collection and rehabilitation activities conducted at French Frigate Shoals (FFS); and the summary results of the Hawaiian Islands Marine Ecosystem Workshop. A substantial amount

of time was devoted to examining the recent population decline at FFS. A lengthy list of recommended priorities relating to FFS was developed for consideration by the Marine Mammal Research Program (MMRP) in research and population management planning for FFS.

A significant amount of time also was spent discussing mobbing-related research findings and the status of plans for treatment or removal of problem males from the affected populations. The Team was extremely disappointed to learn that expected fiscal year 1993 funding for the MMRP would not be sufficient to follow through with the planned treatment of up to 50 percent of the males at Laysan Island with a testosterone-suppressing drug recommended by the Recovery Team at its previous meeting. The Team urged that the necessary funding and permits be secured to allow such treatments as soon as possible.

The Recovery Team acknowledged the pioneering work on the Hawaiian monk seal performed by Karl W. Kenyon, previously with USFWS; Dale Rice, of the National Marine Mammal Laboratory's Pelagic Ecosystem Group in Seattle; and Cliff Fiscus, previously with NMFS. Their contributions continue to play an important role in the conservation of the monk seal. Letters of appreciation were presented to each of them. (W. Gilmartin [808] 943-1239)

Monk Seals Transported to Kewalo Research Facility's New Emergency Care Enclosure

Four underweight yearling female monk seals were collected at French Frigate Shoals (FFS) in January by a Marine Mammal Research Program field party. The FFS population has been experiencing high juvenile mortality, apparently due to reduced prey availability. The four seals were fed formula and whole herring prior to their early February transport to Oahu on the NOAA ship *Townsend Cromwell*. On arrival, they were taken to the newly completed monk seal emergency care enclosure at the Laboratory's Kewalo Research Facility. This enclosure has been inspected by an Animal and Plant Health Inspection Service official to assure compliance with laws and regulations. Here the animals were examined by a veterinarian, and disease screening tests for potentially infectious diseases were negative. The seals have begun to gain weight at the daily rate of 0.5-1.0 kg. All four should be ready for release by April when they will be flown to Midway for introduction to that population. At Midway, their condition and survival will be carefully monitored. (W. Gilmartin, [808] 943-1239)

ADMINISTRATIVE SERVICES

Laboratory Lighting Project Completed

The Western Administration Service Center successfully secured funding from the NOAA Capital Improvement Fund for the removal, disposal, and replacement of all polychlorinated biphenyl (PCB)-ballasted fluorescent light fixtures in the Honolulu Laboratory. The new fluorescent fixtures are .61 m by 1.22 m (2 ft by 4 ft), surface and pendant mounted, energy efficient, and are equipped with electronic ballasts. Mountain West Electric Company was awarded the contract for this $76,000+ project which was completed in about 3 weeks. (K. Yee, [808] 943-1228)

INFORMATION AND TECHNICAL SERVICES

Internet Connection Completed

After nearly 2 years, the long-awaited, often-delayed procurement of an in-house Internet connection has been completed. Honolulu Laboratory personnel now have direct access to the Internet and its vast resources, through the installation of a 56-Kbps line and some software and hardware. The line is being used to access satellite imagery from the University of Hawaii and to utilize the Internet's electronic mail capability. (D. Tieman, [808] 943-1251)

Laboratory Staff Contributes to IT-95 Review

Information Technology 1995 (IT-95), a NMFS-wide centralized data base project, is nearing contract award. This project is designed to procure hardware, software, and communication capabilities. Don Tieman, head of ITS, has spent considerable effort and travel to assist in the procurement effort; conference calls with members of the Technical Analysis Committee to discuss vendor proposal changes and in-house meetings to discuss possible impacts of the project on Laboratory personnel have taken place.

NMFS Headquarters is currently awaiting word on whether the $9 million request has been approved for this year. The contract is expected to be awarded sometime in the next couple of months. (D. Tieman, [808] 943-1251)

PELAGIC RESOURCES INVESTIGATION

Hawaii Longliners Tag and Release Billfish

Since the start of 1991, Hawaii's commercial longline fishermen have tagged and released 119 swordfish, *Xiphius gladius*, 7 other billfish, and 13 bigeye tuna, *Thunnus obesus*. Longline vessels most active in tagging fish include *Seeker II* operated by David Ghigliotty, *Edward G* operated by Tony Geisman, and *Gail Anne* operated by Bobby LaRue. Each of these vessels tagged and released over 30 fish. The Hawaii longline vessels involved in tagging generally target swordfish and tag small (10-40 lb) fish with little market value. They may also tag a few tuna near the beginning of long trips since tuna do not keep as well as swordfish. *Gail Anne* recently tagged a small (10 lb) bluefin tuna, *T. thynnus*. Due to the northward expansion of the Hawaii fishery, bluefin tuna are caught more frequently by this fishery. Tags are provided by the Cooperative Marine Gamefish Tagging Program (CMGTP) at the National Marine Fisheries Service's (NMFS) La Jolla Laboratory and distributed to Hawaii longline fishermen by Robert Dollar of the NMFS Honolulu Laboratory. Recovery of these tags is rewarded with baseball-type tagging caps that carry the CMGTP logo. The Honolulu Laboratory has also been tagging and releasing longline-caught fish on research cruises since 1989, using either CMGTP tags or special tags marked "$REWARD FOR FISH HEAD" to tag billfish that have been injected with oxytetracycline for growth studies. Recovery of these special tags is rewarded by cash payment of up to $100. A total of 102 fish have been tagged with the special cash-reward tags.

The number of fish tagged and released from longline gear in Hawaii (commercial and research cruises combined) totals 339 fish including 142 swordfish; 41 striped marlin, *Tetrapturus audax*; 27 blue marlin, *Makaira mazara*; 16 spearfish, *T. angustirostris*; 56 bigeye tuna and 16 yellowfin tuna, *T. albacares*. The most unusual fish tagged so far were 6 opah (moonfish, *Lampris guttatus*).

To date, of 339 fish tagged and released from longline gear in Hawaii, 2 bigeye tuna and a striped marlin have been recovered. The recaptured fish were released during research cruises in 1989 and 1990—research suggests that bigeye tuna and striped marlin are most likely to survive being caught and released. The low overall recovery rate for all species tagged may imply a high rate of tagging mortality, problems with the reporting of tag recaptures, or a high fish turnover rate in the Hawaii area. There is, however, evidence of underreporting of recaptured fish. Several tags that escaped the attention of fishermen were recovered by Honolulu Laboratory staff at the United Fishing Agency fish auction in Honolulu. Some species such as swordfish are largely sold through market channels other than the Honolulu auction. This fact and reduced Honolulu Laboratory sampling staff activity at the auction (due to budget cuts) may lead to fewer tag recoveries.

Commercial longline fishermen have been helpful in recovering fish tagged by troll fishermen. Hawaii longline fishery recaptures accounted for 50 percent of the striped marlin tag recoveries reported to the SWFSC in 1991. Eight striped marlin and one blue marlin were recovered by the Hawaii longline fishery in 1990-92. Two of the recoveries were striped marlin tagged off southern California, and the rest were marlin tagged off Hawaii. Another long-distance recovery was a skipjack tuna, *Katsuwonus pelamis*, tagged and released over 2,000 miles away in the Solomon Sea and recovered southwest of Hawaii 16 months later by the Hawaii longline vessel *Big Al*.

Troll fishermen in Hawaii have also been increasingly active in the tagging program. The Hawaii troll fishery accounted for 33 percent of the striped marlin and 81 percent of the blue marlin reported tagged in the Pacific by the CMGTP in 1991. Together, Hawaii's trollers and longliners accounted for 10 of the 15 CMGTP Pacific billfish recaptures reported in 1991. Hawaii trollers have tagged over 1,000 blue marlin since 1980, including about 400 in 1991-92. (C. Boggs, [808] 943-1222).

Data Analysis and Archival System Prototype Developed for the North Pacific Transition Zone Driftnet Program

The efficient analysis of large data sets relies in part on effective data management and analytical tools. This is particularly true when analyses involve different types of data (such as satellite data and fisheries data) collected at different scales. During a recent meeting of the Scientific Committee on Research Needs to discuss data base management at the Honolulu Laboratory, Gerard DiNardo, fishery biologist, presented the conceptual model and prototype system for an integrated Data Analysis and Archival System (DAAS) being developed for the North Pacific Transition Zone (NPTZ) Drift-

net Program, in collaboration with Craig Motell of CoastWatch. The system is being developed cooperatively with Al Coan, mathematical statistician, La Jolla Laboratory.

DAAS is modular in design and intended for use in storing, interpreting, and diagnosing physical and biological data collected in the NPTZ. The architecture of the DAAS is illustrated in Figure 1. System modules include data base, satellite image processing, mapping, data manipulation and analysis, graphics, and report writing. The integration of analytical tools with data base management provides users with an interactive system for efficient data management, browsing, and analysis. DAAS is UNIX based and networked to a SUN workstation which acts as a file server. The benefits of using a UNIX-based workstation system rather than a DOS-based PC system include (1) reduced computer run time, (2) increased storage capacity, (3) easy system updating (only have to update the system once), and (4) multi-user simultaneous system access.

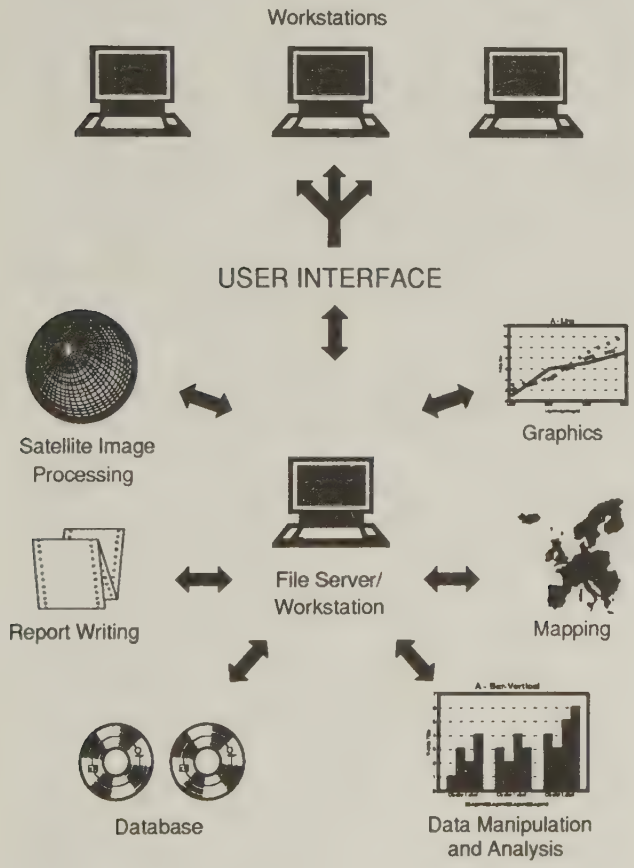

Figure 1. Data Analysis and Archival System (DAAS).

Current prototype development is limited to the data base and mapping modules. Instead of developing the prototype system from scratch, existing systems and software were identified and evaluated based on desired attributes of the conceptual model. By using existing systems, development time and cost are minimized.

For the mapping module, the software package Generic Mapping Tools (GMT) is being explored. GMT is a free, public domain software package that can be used to manipulate columns of tabular data, time series, and gridded data sets and to display these data in a variety of forms ranging from simple x-y plots to maps and color, perspective, and shaded-relief illustrations. GMT uses PostScript page description language and is written as a set of UNIX tools.

The Naval Environmental Operational Nowcasting System (NEONS) is being evaluated for use with a relational data base in the data base module. NEONS was developed by the U.S. Navy and is used in many interactive information and processing systems for meteorology, oceanography, and hydrology. NEONS is a software package that provides a set of tools to access, create, and manage environmental data which are stored in a NEONS schema within a relational data base. The Navy's NEONS Data Browser is being examined as an interface between NEONS and the relational data base. The NEONS Data Browser allows users to select, locate, and access needed data sets through a series of temporal and spatial queries. The accessed data set can then be exported to another file or application for data analysis or visualization. At present, NEONS manages only environmental data using EMPRESS as the relational data base management system. However, NEONS supports SQL protocol and should allow conversion to any relational data base supporting ANSI SQL, including ORACLE version 7 (ORACLE version 7 is needed for compatibility with NEONS since it supports a binary data type such as that used by satellite imagery). The conversion of EMPRESS to ORACLE is being evaluated as well as expanding permissible data types to include fisheries data. (G. DiNardo, [808] 943-1259)

INSULAR RESOURCES INVESTIGATION

Report Completed on Status of the 1992 Lobster Fishery

The annual catch and effort in the Northwestern Hawaiian Islands' (NWHI) commercial lobster fishery was 424,445 spiny and slipper lobsters caught in

721,682 trap-hauls. In April 1992, an amendment to the Fishery Management Plan (FMP) was passed that created an annual closed season (January-June) and an annual catch quota. The fishery was subsequently closed through the end of June 1992. During the July-December fishing season, 353,212 lobsters (81 percent of the final quota) were caught in 582,801 trap-hauls.

The average annual catch-per-unit effort (CPUE) of 0.59 lobsters per trap-haul was only 5 percent higher than the 1991 value, indicating that the lobsters have not recovered appreciably from the 1990 drop in CPUE.

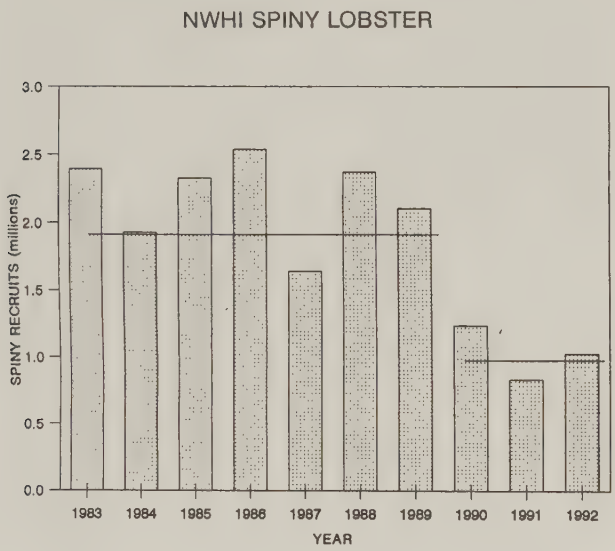

Figure 2. Estimated annual recruitment of age-3 spiny lobster to the Northwestern Hawaiian Islands fishery 1983-92. Horizontal lines indicate the average annual recruitment for the years 1983-89 and 1990-92.

Analyses based on commercial fishery data from 1983 through 1992 indicated that recruitment to the fishery dropped 50 percent after 1989 (Fig. 2). Recent research suggests that productivity has declined for a number of NWHI species (seabirds, monk seals, reef fish) since the early 1980s due to a climatic-linked oceanographic event. There is some evidence that lower lobster recruitment levels may also be caused by a reduction in lobster spawning biomass.

Results of forward simulation population modeling incorporating reduced recruitment suggest that the lobster stocks may take at least 2 years to rebuild to FMP-mandated CPUE levels and that future exploitation of the lobster population should be at lower levels than during the 1983-89 period. (W. Haight, [808] 943-1236)

FISHERY MANAGEMENT AND PERFORMANCE INVESTIGATION

Application of Fractional Licensing in the Hawaii Longline Fleet

Ralph E. Townsend, associate professor of economics at the University of Maine, and Samuel G. Pooley, industry economist at the Honolulu Laboratory, recently completed a manuscript in which they apply an alternative effort management scheme to the Hawaii longline fishery. The Hawaii longline fishery is currently under a moratorium on new entry while the Western Pacific Regional Fishery Management Council sorts out options for controlling its rapid growth over the long term.

"Fractional licensing," introduced by Townsend in an earlier paper, is an alternative to simple limited-entry (license limitation) or individual transferable quotas (ITQs) in that it allows a fishery manager to vary the number (and potentially fleet-wide fishing power) of vessels in a fleet through direct market mechanisms on fishing capacity and effort. Whereas ITQs attempt to regulate a fishery through allocating fractions of the output (quota) to fishing vessels, "fractional licenses" allocate to each license holder a portion of the optimal or target number of vessels in a fishery. This is done by issuing vessel owners with divisible licenses or "fractions" in a manner directly analogous to ITQ shares. These fractional licenses would be freely tradeable (including direct sales, leases) but would also be adjustable by the fishery manager.

In the example used by Townsend and Pooley, if the fishery manager (in this case the Council) wanted to reduce the potential number of vessels in the Hawaii longline fleet from 166 (the current number of licenses, but some of the vessels are actually inactive or operate part-time) to 100 (approximately the number of currently full-time longliners), then each license holder (of both active and inactive vessels) would be issued 100 "fractions" of a license (100/166 of a whole fractional license). However, to go fishing, a license holder must hold 166 fractions, that is, a whole fractional license (166/166). Therefore, longline vessel owners intending to go fishing would have to purchase the difference, 66 fractions (to make 166/166 of a fractional license), from other longline vessel owners to obtain the full fractional license. (Vessel owners would probably be required to turn in 166 fractions to the fishery manager in exchange for a current year permit in order to go fishing). Those without a full fraction, 166 fractions, either because they did not buy addi-

tional fractions or they sold their fractions, could not fish. In either case, the number of fully licensed longliners would decline from 166 to 100 vessels.

This procedure would encourage currently inactive vessels to give up their licenses (they would be "compensated" by the active vessels through the purchase of some or all of their 100 fractions), thus clarifying for fishery managers the level of effective fishing power in the fleet, while rationalizing the current rules of license transferability (only one license transfer is allowed during the period of the current longline moratorium: 1991-94). Perhaps more importantly, it would reduce the potential fishing effort in the fishery to 100 longline vessels, rather than the current (but unrealized) potential of 166 longliners. Although the owners of active vessels would have to purchase part of a license required to continue fishing (the 66 fractions), the economic value of fractional licenses would be greater than the current non-fractional licenses, which have limited transferability. For simplicity, these full fractional licenses (166 fractions) would be redenominated as 100 fractions (100 percent of a new full fractional license) when the current year permits were issued.

If the Council decided to further reduce fishing effort, there would be a market within the existing fractional license holders for the fractions now required to complete a full license. For instance, if the Council decided to decrease the size of the fleet from 100 to 80 vessels, it would require 120 fractions of a license (or 1.2 old licenses per vessel) to obtain a permit to fish in the current season. Since each permittee would have 100 "fractions" of a license from the previous season, those who wished to continue fishing would again have to purchase the difference (20 "fractions") from other vessels that chose not to fish. Conversely, if the Council chose to increase the size of the fishery, it could issue additional licenses at the original fraction 100/166. The Council could also "tax" increases in fishing power (termed "upgrading" by the Council) by requiring vessels which upgrade to have an additional fraction in order to obtain a fishing permit (for example, 110 fractions instead of 100).

The choice of 100 longline licenses as an illustrative number is entirely arbitrary from a scientific viewpoint. There is no biological or economic information in this fishery that can be used to establish an optimal level of fishing effort. It appears that many longliners in the Hawaii fleet have quite low economic returns, but this may be caused by the limited transferability and limited upgrading which is allowed under the current moratorium. The fractional licensing approach allows a more reasoned approach to asset management by longline vessel owners while at the same time allowing public control of overall fishing capacity through the fishery management process.

While a fractional license system does not have the fine tuning capabilities of an ITQ system in terms of biological production, it is substantially simpler to administer and enforce, and it allows active fishing vessel owners and captains to maintain an important part of the fishing lifestyle: the freedom to catch as much as possible without regulatory restriction. At the same time, through the relationship between fishing power and catch, it would also allow a fishery manager to practice adaptive management (responding on a regular basis to changes in fishery parameters) without the economic distortions common in quota, trip limit, and gear restriction management programs and without the capital stuffing problems of simple limited-entry programs.

The Council is considering a number of limited-entry alternatives for replacing the longline moratorium when it expires in 1994. Fractional licensing is just one of the potential management measures under consideration.

The Townsend and Pooley paper is being reviewed by a fisheries journal. (S. Pooley, [808] 943-1216)

PELAGIC FISHERIES RESOURCES DIVISION

La Jolla, California

STOCK ASSESSMENT AND FISHERY IMPACT ANALYSIS PROGRAM

Study Completed on Pelagic Driftnet Fishery for Sharks and Swordfish

Al Coan, Mathematical Statistician; Dave Holts, Fishery Biologist; and Doyle Hanan of California Department of Fish and Game (CDF&G) have completed a study of California's drift gillnet (DGN) fishery for swordfish and sharks. This study includes the history of the fishery, catch and fishing effort summaries, California regulations, and summaries of biological data for the major species caught. Data used in the study were obtained from the California logbook system, landing receipts,

the California logbook system, landing receipts, and market samples collected over a period from 1981-82 through 1990-91.

Logbooks were collected from skippers of California DGN vessels under a mandatory logbook system implemented in 1980. Data in the logbooks include catches (number of fish) by species, date, size of net mesh, length of net, hours soaked, set number, geographical position, and other information such as the vessel permit number and vessel registration number. Commercial fish buyers were required to complete a landing receipt for each landing purchased. The buyers recorded the species landed, quantity (pounds), price paid, and the fishing gear used. CDF&G port samplers recorded number and length by species when catches were unloaded at commercial markets.

During the 10-year period covered by the study, the fishery evolved rapidly from a small nearshore enterprise targeting common thresher sharks, *Alopias vulpinus*, and shortfin mako shark, *Isurus oxyrinchus*, in the late 1970s to a major California fishery targeting sharks as well as swordfish, *Xiphias gladius*, and with valuable bycatch such as the opah, *Lampris guttatus*. Because of several emerging fishery conflicts and concerns for the fish resources, the state legislature enacted a series of laws regulating the new fishery. Major changes in nearly every aspect of the fishery occurred including boat and gear, fishing technique, fishing area and season, and targeted species.

The size of vessels in the DGN fleet varied between 20 and 90 feet in length. The nets used were usually 1,463.04 m to 1,828.80 m (4,800 to 6,000 ft) long and were used to fish at a depth of 5.49 m to 7.32 m (18 to 24 feet) (Fig. 1). Nets were constructed of 3-strand #24 to #30 twisted nylon, tied to form meshes averaging 33.02 cm to 48.26 cm (13 to 19 inches) stretched mesh. Fishing operations were conducted only at night.

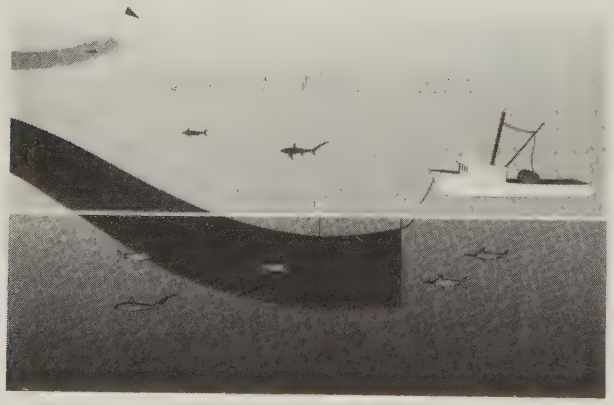

Figure 1. General view of California drift gillnet vessel operations.

In the first 5 years of the study period, total annual effort nearly doubled to a peak of 11,000 sets in the 1986-87 fishing season and subsequently declined to a low of 4,000 sets in the 1990-91 season. This decline coincides with increasing regulations governing this fishery, including regulations to limit entry and a spring closure on fishing for sharks.

The distribution of fishing effort shifted geographically from the nearshore southern California Bight in the early 1980s to a more even distribution northward and offshore in the 1990s. The fishery now operates in an area between San Diego and Cape Mendocino. In 1986-87 and 1987-88, it extended into the waters off Washington and Oregon (Fig. 2).

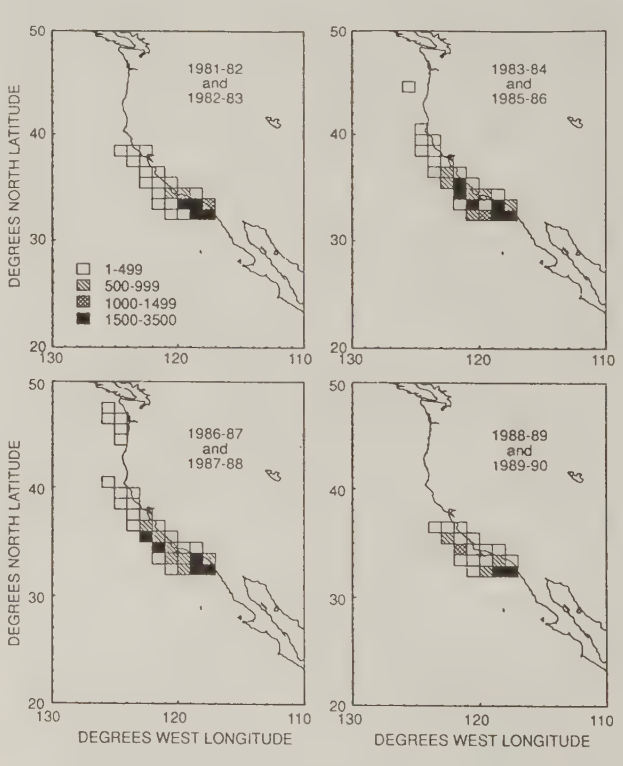

Figure 2. One-degree geographical distribution of fishing effort (number of sets) from California drift gillnet logbook data for the 1981-82 through 1989-90 fishing seasons.

The number of vessel unloadings increased to a high of 3,500 in the 1983-84 season and decreased steadily to a low of 1,500 in the 1990-91 season (Fig. 3a). The number of DGN vessels in the fishery peaked in 1985-86 at 350 and decreased to less than 200 in the 1990-91 season (Fig. 3b). Landings per vessel decreased markedly from a high of 13 in the 1982-83 season to a low of 7 in the 1988-89 season (Fig. 3c).

Catches varied by fish species, season, and year. The 10-year mean annual landing was 2 million lbs for swordfish, 1 million lbs for common thresher, 262 thousand lbs for shortfin mako shark, and 80 thousand lbs for opah. Average landings over the last five years were quite close to the 10-year average although there is a declining trend in the total catch landed for most species. Prices per pound paid during the period ranged from $2.00 to $4.00 for swordfish, $1.00 to $2.00 for shark, and $0.25 to $0.50 for opah.

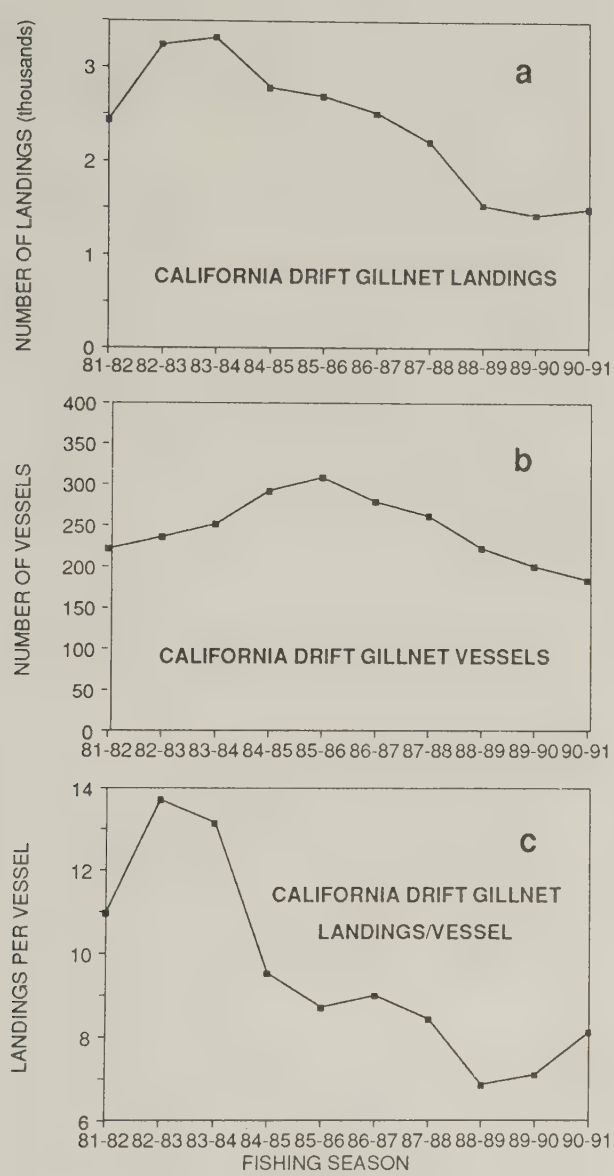

Figure 3. Number of landings (a), vessels (b), and landings per vessel (c) for the California drift gillnet fishery, 1981-82 to 1990-91.

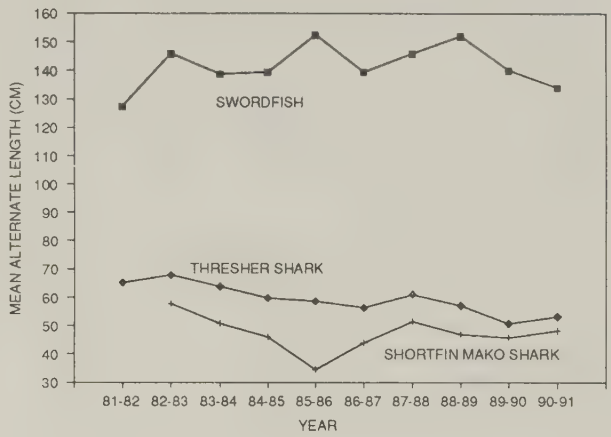

Figure 4. Mean alternate length of swordfish, common thresher sharks, and shortfin mako sharks sampled at California markets, 1981-82 to 1990-91 fishing seasons.

Average sizes of swordfish landed varied, but with no consistent trend. Average sizes of shortfin mako sharks decreased from 1982-83 through the 1985-86 fishing seasons but rebounded in the 1987-88 season. Average length of thresher sharks, however, decreased 30 percent over the period (Fig. 4), coinciding with a decrease in landings as well.

A number of problems and conflicts occurred during the first 10 years of the fishery including bycatch of marine mammals and striped marlin, and conflicts with commercial harpoon fishers and recreational fishers. Most of these were resolved through the cooperative efforts of the principals involved.

Some concerns expressed when the fishery first started continue today. Specifically, high shark catches historically have not been sustained for shark fisheries and, in fact, tend to decline significantly or "crash" rather suddenly. The California DGN vessels catch primarily juvenile sharks within the Southern California Bight, especially shortfin mako sharks, and more recently, common thresher

sharks. In response to declines in the common thresher shark catch and in average size of fish, the State virtually eliminated the directed common thresher shark fishery with area and season closures. If the number and size of shortfin mako sharks caught show similar declines, management controls may be appropriate for this species as well.

The incidental catch of marine mammals is apparently low and not compromising any stocks although the potential remains; therefore, NMFS is continuing to monitor the fishery. Bycatch of other fish does not appear to be adversely impacting other species except for the incidental catch of blue sharks which may have an adverse effect on local stocks. Nonetheless, the driftnet catch is controversial and generates three general types of controversy: (1) politically—to the environmentalists with the gray whale, minke whale, sea lion, dolphin, and blue shark bycatches and to the sportfishermen with the striped marlin bycatch; (2) economically — to the swordfish, salmon, albacore, and opah fishermen through lost revenue due to bycatch of these species; and (3) as a loss of novelty species — of special interest to this group are the megamouth shark and white shark.

By incorporating both landing receipt and logbook data along with market sampling data, authors of this study summarized important facets of the California drift gillnet fishery. The quality of all data collected for the DGN fishery, while relatively high in some areas, can be improved. The logbook system is very good and is accompanied by high coverage rates. There is some confusion in the way logbooks are completed, which could be eliminated if more complete instructions were provided to the fishermen. The current landing receipts might also be improved with better instructions to buyers and with inclusion of more specific gear codes. Coverage rates for market sampling are comparable to those of other California fisheries monitored by CDF&G. The quality of length-frequency data may be improved by instituting a formal sampling plan that takes into account the species landed, month of landing, and optimum sample size. (D. Holts, [619] 546-7186 and A. Coan, [619] 546-7079)

Albacore Presentation Made to Industry

The American Fishermen's Research Foundation (AFRF) held its Board of Directors' meeting at the Southwest Fisheries Science Center (SWFSC) in February and received a report on albacore fishery statistics and research results from the SWFSC staff. SWFSC staff attending the meeting were Acting Science and Research Director Richard Neal; Pelagics Fisheries Resources Division Chief Gary Sakagawa; Stock Assessment and Fishery Impact Analysis Program Leader Norm Bartoo; and Fishery Biologist Dave Holts.

The report covered a summary of catch, effort, and catch-per-unit effort for the 1992 North Pacific season and the 1991-1992 South Pacific season; based on voluntary logbook data from the U.S. fleet, size composition of albacore caught in the North and South Pacific fisheries based on port and observer sampling, comparison of size composition data taken at sea by observers and at shoreside by port samplers, and results of observer sampling for driftnet-damaged fish in the North Pacific.

Meeting participants discussed cooperative efforts between the industry and the AFRF for North Pacific albacore research projects for 1993. In 1993, the AFRF will assist NMFS by offsetting the costs associated with processing logbook and biological sampling data. Additionally, volunteer troll vessels will take NMFS observers aboard trips in the North Pacific to collect size composition data on albacore and to look for residual driftnet damage. The AFRF will also provide needed fish samples for biological investigations aimed at validating assumptions used in stock assessments. (N. Bartoo, [619] 546-7073)

MULTISPECIES DATA COLLECTION AND EVALUATION PROGRAM

1992 California Gillnet Observer Data Compiled and Edited

Fishery Biologist Alan Jackson of the Multispecies Data Collection and Evaluation Program reports that data collected during 1992 by the California Gillnet Observer Program have been compiled, edited, and made available to researchers and managers.

Since 1990 the NMFS, under the authority of the Marine Mammal Protection Act and with the cooperation of the California Department of Fish and Game, has placed biological technicians (observers) aboard fishing vessels to collect information on marine species associated with the California gillnet fisheries. The types of information collected include incidental mortality of marine mammals and other protected species, fishing effort, and catch.

In 1992, NMFS observers were aboard 852 fishing trips made by 136 vessels for a total of 2,974 net pulls (Fig. 5). Observers counted a total of 92 cetaceans, 481 pinnipeds, 334 birds, and 5 turtles killed in the gillnets. The most frequently caught finfishes (in numbers of fish) were white croaker (8,655), Pacific mackerel (7,377), California halibut (6,608), bat ray (5,944), and California skate (3,538). Observers recorded length measurements for 4,811 California halibut, 797 blue shark, 677 spiny lobster, 348 barred sand bass, and 233 Pacific sardine. (A. Jackson, [619] 546-7048)

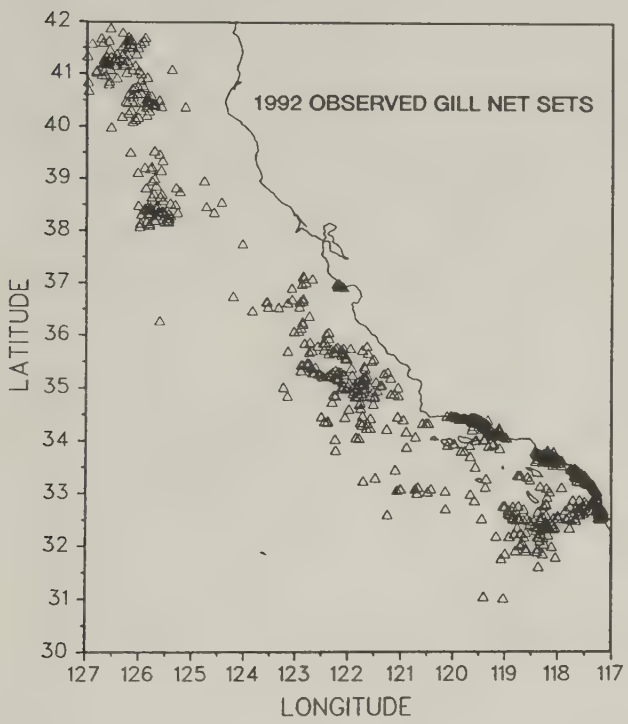

Figure 5. Locations of net pulls made by the California set- and drift-gillnet fisheries observed by the NMFS during 1992. Δ = each net-pull location.

PELAGIC ECOSYSTEM MODEL DEVELOPMENT PROGRAM

Analysis Completed of Maldive Tagging Data

In 1990, a very successful tuna-tagging program was conducted in the Maldive Islands by the Maldives Ministry of Fisheries and Agriculture with the help of the Indo-Pacific Tuna Development Programme (IPTP), a United Nations Food and Agriculture Organization program headquartered in Colombo, Sri Lanka. In February, Pelagic Ecosystem Model Development Program Leader Pierre Kleiber traveled to Colombo to assist in the analysis of the tag-return data and to make suggestions for planning a subsequent tagging campaign. Kleiber worked together with IPTP scientist Michel Bertignac to put together an analytical tag attrition model on an IPTP computer and to do a preliminary analysis of the Maldive skipjack returns. A draft manuscript has been prepared for publication by IPTP (Bertignac and Kleiber, "Analysis of Maldives Islands tuna-tagging data with a spatially aggregated attrition model").

The model allows the estimation of attrition rate (natural mortality plus emigration and minor components such as tag shedding), catchability, and fishing mortality—exploitation rate can be calculated as well. The estimates of exploitation rate are sensitive to whether returns in the first month following tagging are included in the analysis (Fig. 6). The results are also somewhat sensitive to the assumed tagging survival rate and proportion of recaptured tags that are returned (Fig. 7). There is good reason to believe that these factors are favorable in the Maldives operation; that is, the combined factor (alpha) has a value close to 1.0. By rule of thumb, the exploitation rate for a fully exploited population is in the neighborhood of 0.5. Thus it appears from the two figures that the Maldives skipjack population is less than fully exploited.

The above results are preliminary because the natural mortality is confounded with emigration. A more complicated, spatially disaggregated model is planned that would allow mortality and movement effects to be disentangled. The Maldives

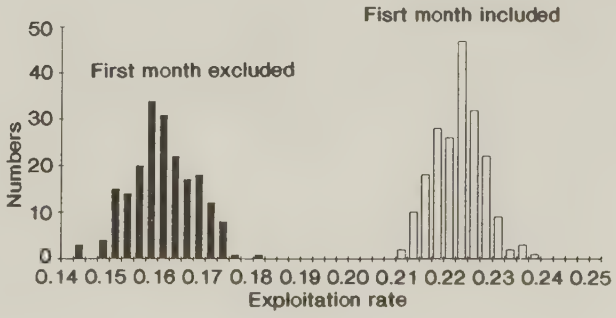

Figure 6. Frequency distributions of exploitation rate estimates by Monte-Carlo technique based on best-fitting parameters with and without the first month following tag release. Exploitation rate = percentage of total mortality due to fishing.

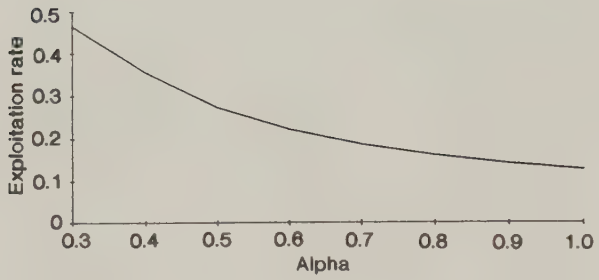

Figure 7. Effect of assumed value of alpha, the combined survival of tagging and proportion of recaptured tags that are returned, on exploitation rate estimated from all data sets combined, with the first month of each eliminated.

Ministry of Fisheries and Agriculture is planning a new tagging program, taking advantage of the experience of the first program and the results of the analysis described above. (P. Kleiber, [619] 546-7076)

TIBURON LABORATORY

Tiburon, California

GROUNDFISH PHYSIOLOGICAL ECOLOGY INVESTIGATION

Fecundity Compared in Yellowtail Rockfish from California and Washington

The commercially important yellowtail rockfish, *Sebastes flavidus*, ranges from Alaska to southern California, but it is most abundant and economically important from Oregon to British Columbia, Canada. In the early phases of the Groundfish Physiological Ecology Investigation's research on yellowtail rockfish, staff biologists examined fish from throughout the range and found that southern populations differed from northern populations in many life-history traits. Generally, California yellowtail rockfish were younger in average age, slower in growth, more heavily impacted by diseases and parasites, had less abundant mesenteric fat stores, and exhibited longer reproductive life spans than fish in Washington coastal waters.

Since measures of reproductive effort are critical to fishery science and management, Fishery Biologist Maxwell Eldridge and Biological Science Technician Brian Jarvis conducted a multi-year study to compare fecundities of Washington yellowtail rockfish with those of California fish. The Washington population is heavily fished commercially and is now separately managed because of a decade of sustained declines in abundance. The California population, in contrast, is mostly a recreationally fished population that has experienced low fishing pressure. From reproductive years 1988-89 to 1990-91, Eldridge and Jarvis collected and examined 308 adult female yellowtail rockfish from central Washington and compared their weight-determined fecundities with those measured in 407 California fish taken from 1985-86 through 1991-92.

For geographic comparisons, data were pooled for all years within each location, assuming that the observed patterns represented the natural variation occurring within each population. Washington fish averaged 11.9 years of age and 40.8 cm standard length, California fish averaged 15.4 years and 36.3 cm. The mean absolute fecundity of Washington rockfish was 905,000 eggs/female versus 523,000 for California.

In earlier studies of temporal comparisons, Eldridge and Jarvis found that fecundity was related in linear or sigmoidal fashion to body length and somatic (total body weight minus gonad weight) wet weight, and asymptotically to age. Thus, they divided fish into young (≤14 year) and old (≥15 year) categories and analyzed them separately for geographic differences. As illustrated in Figure 1, Washington fish clearly were younger, larger, and generally more fecund than California fish. Northern fish also showed less variability in fecundity (coefficients of variation, 40.3 percent versus 48.2 percent). In similar fashion, California fish had 17 percent lower relative fecundities (egg numbers per gram of somatic body weight) than Washington fish.

Rate-specific patterns, when subjected to analyses of covariance, indicated that young yellowtail rockfish displayed the most significant geographic differences. The age-specific fecundities of Washington fish differed most significantly from those of California fish ($P>0.01$), while length-specific fecundities differed at the $P>0.05$ level. Weight-specific fecundities were not significantly different. Older fish, on the other hand, displayed much greater variability, less discernible patterns, and were significantly different ($P>0.05$) only in length-specific fecundities.

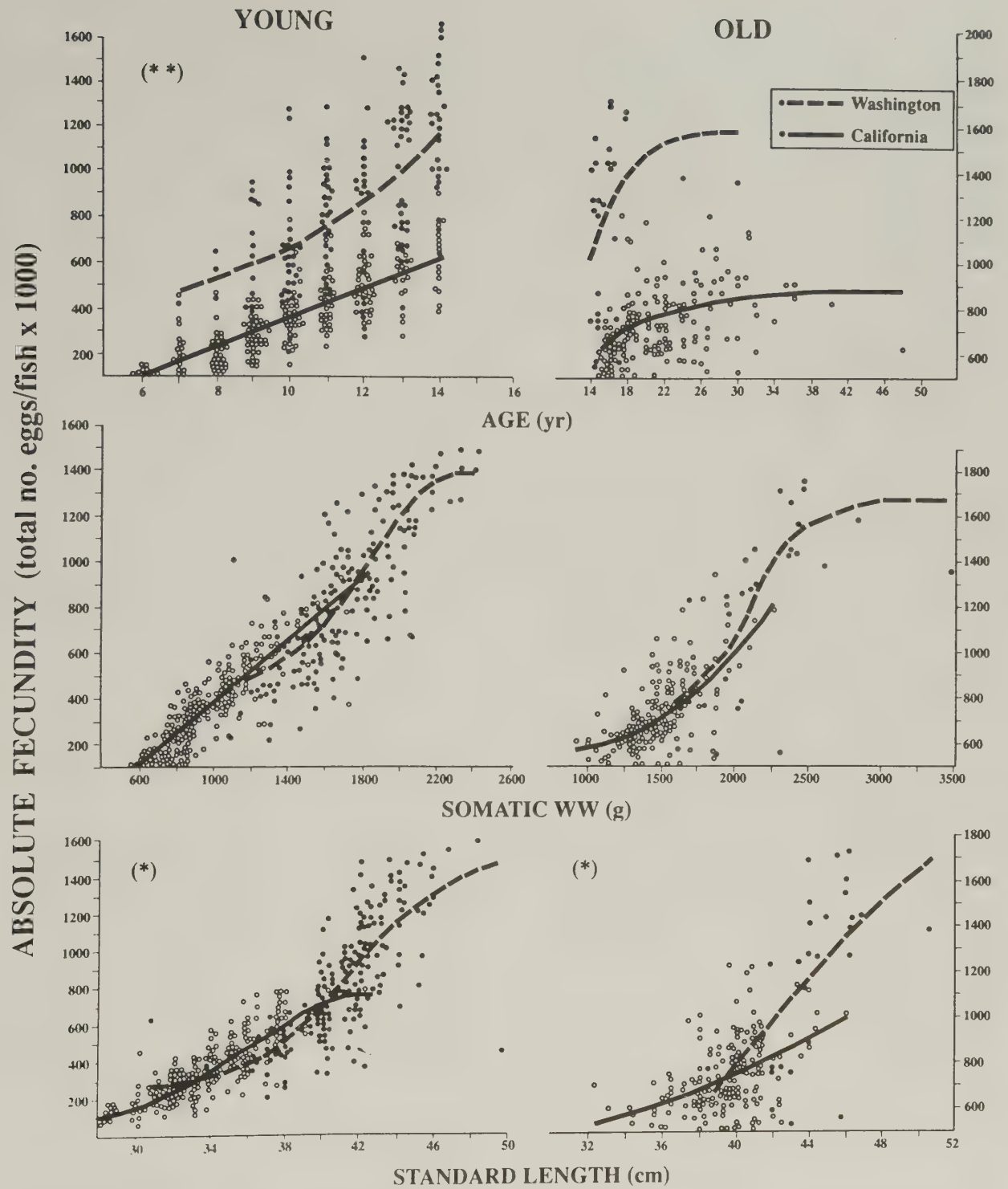

Figure 1. Absolute fecundities of young (≤14 yr) and old (≥15 yr) yellowtail rockfish from California and Washington according to age, somatic wet weight, and standard length. Curves are presentations of best-fit curves resulting from curve fitting analyses. * = significant difference at 0.05 level. ** = highly significant difference at 0.01 level.

These research findings have several implications for understanding the differences in the reproductive life histories between different populations of rockfishes. When combined with results of previous studies which showed significant interannual variability in growth rates and parasite loads in younger versus older fish, these results indicate that age may play an important role in how fish respond

to environmental differences and how yellowtail rockfish allocate energetic resources to growth, maintenance, and reproduction. Also, there is some indication that senescence (effects due to aging) may occur in the reproductive output of these long-lived fishes. Lastly, younger yellowtail rockfish from the center of their distribution appear to be more fecund in absolute numbers of eggs and on length-specific bases than their counterparts from the southern edge of their distribution. (M. Eldridge, [415] 435-3149)

GROUNDFISH COMMUNITIES INVESTIGATION

Diet of Sablefish Related to Size and Depth of Habitat

Management of the recently expanded fisheries for sablefish and other inhabitants of the outer continental shelf benefits from knowledge of the trophic relations between the sablefish and the other inhabitants. To supply this knowledge, Fishery Biologists Tom Laidig and Peter Adams have analyzed the gut contents of specimens from 286 bottom-trawl collections made at depths from 50 to 700 fathoms during 7 research cruises between 1988 and 1991.

These collections included 1,868 sablefish, which over the range of sizes sampled (201 to 820 mm SL) showed a change in diet (Fig. 2). Fishes were the major prey for all sizes but were taken by only 45 percent of the smaller individuals and by about 80 percent of the larger ones. Scorpaenids, *Sebastolobus* spp. and *Sebastes* spp., dominated the diet, occurring in about 14 percent of the specimens and constituting about 35 percent of the diet's volume. Next in prominence was the hake, *Merluccius productus*, which occurred in 5 percent of the fish and represented 11 percent of the diet volume. Trailing far behind these were a variety of midwater fishes, including myctophids and bathylagids (4 percent occurrence, 3 percent diet volume). Two adult sablefish had each taken a single small sablefish.

A variety of invertebrates were especially important to smaller sablefish, less so to larger ones (Fig. 2). Cephalopods, however, were taken with similar frequency by all sizes (with larger individuals taken by larger sablefish). The major cephalopod prey was squid (9 percent occurrence, 7 percent diet volume), especially *Loligo opalescens*, but octopods also were important. Next in prominence were heteropods (10 percent occurrence, 4 percent diet volume), almost all *Carinaria* sp. Other prey of decreasing importance included gelatinous zooplankters, most of them thaliaceans (6 percent occurrence,

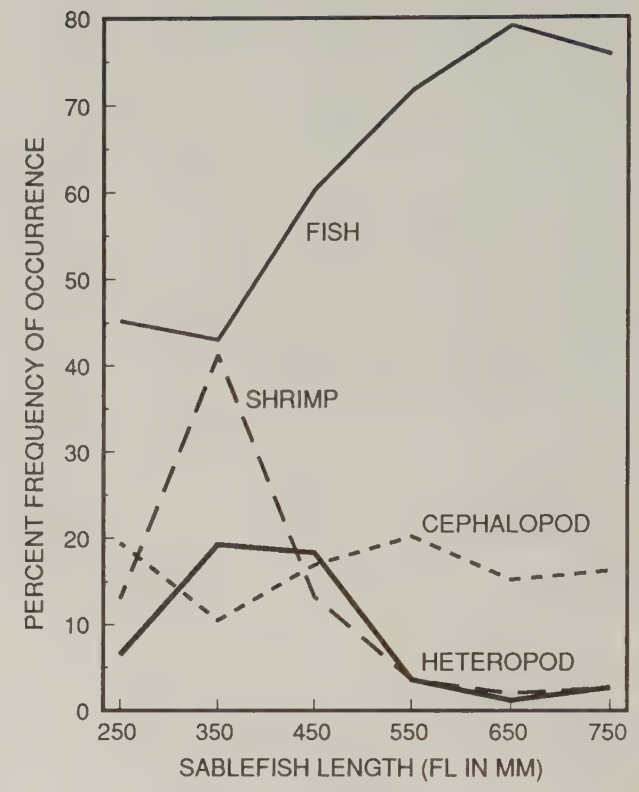

Figure 2. Frequency of occurrence of major prey categories of sablefish with increasing fish size.

3 percent diet volume): natantian decapods (6 percent, 2 percent diet volume), mainly *Segestes similis*, and an assortment of smaller crustacea, including mysids, gammaridean amphipods and euphausiids (9 percent occurrence, 1 percent diet volume). One anomalous result was that while larger sablefish generally took larger prey, the reverse occurred when the prey were heteropods or the smaller crustacea listed in the last category above. (P. Adams, [415] 435-3149)

GROUNDFISH ANALYSIS INVESTIGATION

Time Series of Larval Rockfish Otolith Growth Studied

Larval growth rate is sensitive to environmental conditions and can have a major impact on recruitment to the exploitable stock. Thus, assessing the effects of fluctuating oceanographic conditions on larval growth, both within and among years, may help clarify the influence of physical factors on reproductive success. This was the subject of an in-

vited talk given recently by Fishery Biologist Stephen Ralston at the International Symposium on Otolith Research and Application held at Hilton Head, South Carolina. To evaluate time-specific growth and its dependence on environmental factors, daily otolith increment widths were used as a measure of larval growth rate. Data from five species of rockfish, *Sebastes* spp., collected during annual (1985-89) surveys of pelagic juvenile rockfish abundance off central California were analyzed.

Daily increment widths were measured along the postrostral otolith radius (*OR*) from the sagittae of pelagic juveniles. The data were collected using a compound microscope equipped with a video imaging system interfaced with a personal computer. Given terminal specimen age, the known date of capture, and a "back-calculated" series of daily increment widths, it is possible to associate the width of each increment with both specimen age and the calendar date at the time it was formed. Increment width data measure otolith growth rate directly, that is, $\mu m/d = dOR/dt$. Validation of a 1:1 relationship between increment count and specimen age has been demonstrated for young-of-the-year shortbelly rockfish, *S. jordani*. Only fish that ranged 2-50 d in age were included in the estimation of calendar date time series of otolith growth because increments were not reliably measured in younger fish, while in older individuals, accessory primordia (a new point of growth) began to form at the time of juvenile transformation.

The combined effects of larval age and calendar date on otolith growth rate were estimated with analysis of variance. A simple two-factor additive model accounted for 85-95 percent of the variation in the logarithm of larval otolith growth rate. More importantly, there was little evidence of factor interaction. Time series of the calendar date effect were then calculated from the least-squares means among the various 25 species-year combinations. Results showed that within any particular year, the growth time series of the 5 species were positively correlated (46 of 50 cases), but distinct interannual differences in pattern were observed.

A single fit of an autoregressive multiple regression model to daily time series of shortbelly rockfish, *Sebastes jordani*, otolith growth rate over the full 5 years of data was obtained (Fig. 3). The calendar date series were strongly autoregressive (Φ=0.818) within each year, indicating significant inertia to the otolith growth process and a lag in otolith response to environmental perturbations. The model also detected significant dome-shaped parabolic effects of sea surface temperature (SST) and sea level anomaly, but no effect due to upwelling. Maximum growth

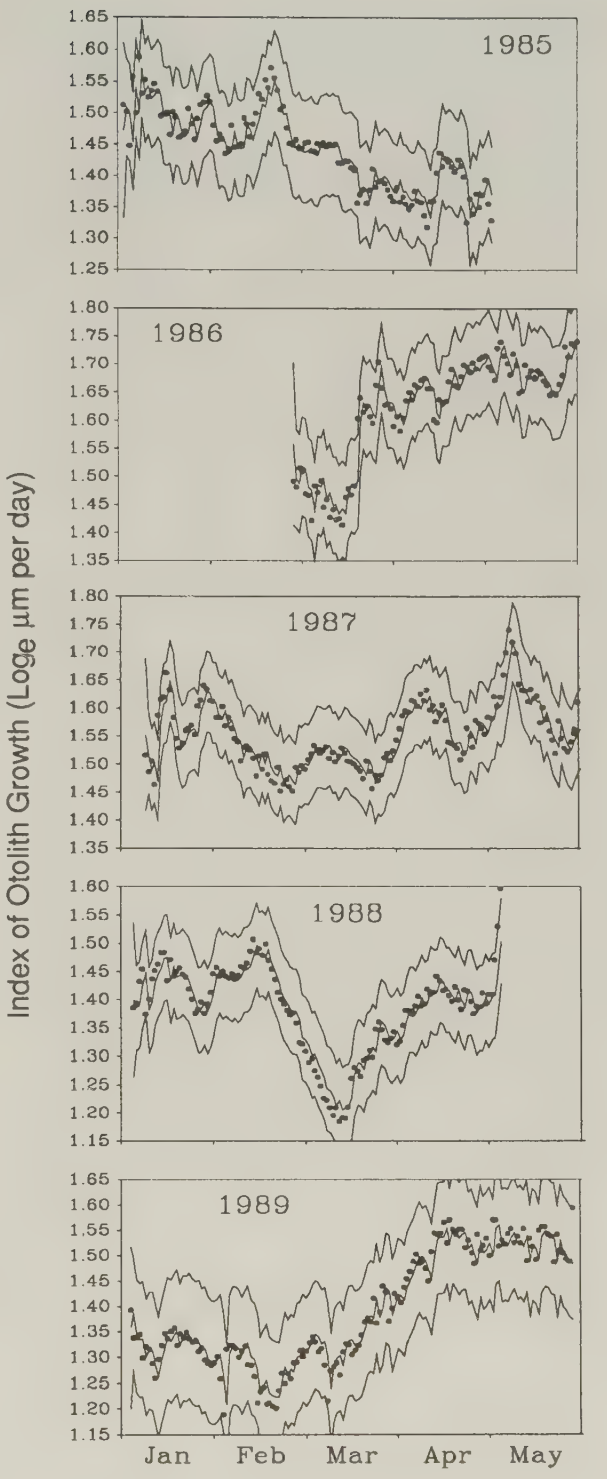

Figure 3. The effect of calendar date on the growth rate of shortbelly rockfish otoliths (1985-89). Closed circles represent the date least-squares means of $\log_e[\mu m/d+0.5]$. The solid line shows the fit of the autoregressive multiple regression to the data; the dotted lines encompass the 95-percent confidence intervals for the predicted values.

occurred at approximately median values of SST (11.7 °C) and sea level anomaly (0 mm) (Fig. 4).

Substantial differences in otolith growth were observed among years. These fixed-year effects are thought to be related to the pattern of upwelling during the winter spawning season, with alternating upwelling and downwelling episodes enhancing larval otolith growth. However, based upon 5 years of data (1985-89), there was no evidence that years of good larval growth were associated with improved survival to the pelagic juvenile stage (Fig. 5). (S. Ralston, [415] 435-3149)

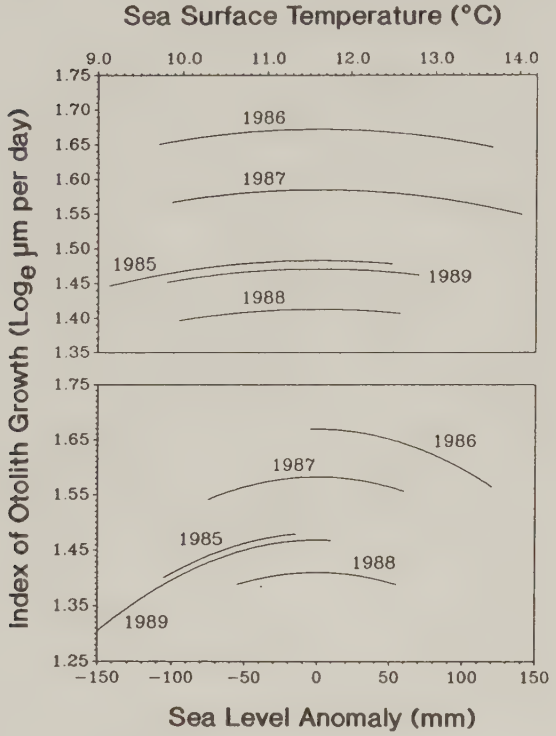

Figure 4. Predicted sea surface temperature and fixed-year effects on the growth rate of larval shortbelly rockfish otoliths (upper panel); predicted effects of year and sea-level anomaly at San Francisco on larval growth (lower panel).

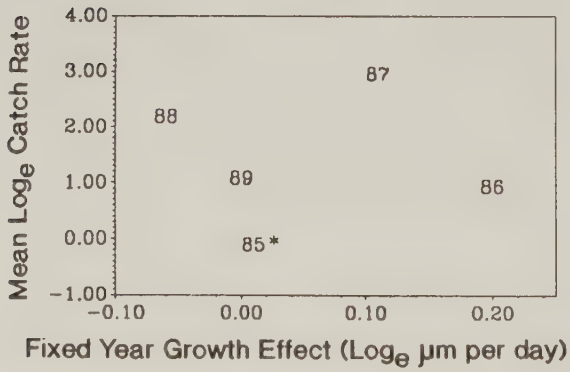

Figure 5. Relationship between the abundance of pelagic juvenile shortbelly rockfish and the fixed year larval growth effect. * = abundance estimate for 1985 based on limited data.

INFORMATION TECHNOLOGY SERVICES

IT-95 Year Zero Option Implementation Begins

The procurement of the IT-95 distributed systems is nearing the selection/approval process. Because of critical budget constraints, the current plan is that only systems at the three mandatory sites (Seattle-Sand Point, Miami, and Headquarters) will be installed with operational support during the initial phase. Based on funding in the following years, the systems at the optional sites (La Jolla, Honolulu, Auke Bay, Seattle-Montlake, Monterey, and Woods Hole) will be installed according to a phased plan. The IT-95 fund covers the procurement of the system hardware and software. System start-up costs, recurring annual operational costs, and software conversion costs are not covered.

To partially compensate for the lack of operational funds and to begin the software conversion process, a basic plan was developed and recommended during the National Data Management Committee meeting in November 1992 for the equitable distribution of the Year Zero funds to the IT-95 sites to prepare their users for the new IT-95 hardware and software platforms. The plan was approved in January by NMFS Director Dr. William Fox for implementation with the Year Zero fund being held in NMFS Headquarters (HQ) for the procurement of specific resources needed for all nine IT-95 sites: Woods Hole, Miami, La Jolla, Honolulu, Monterey, Seattle-Sand Point, Seattle-Montlake, Auke Bay, and NMFS HQ. The procured resources will provide the start-up training for users for a smooth transition to the new IT-95 environment.

The specific resources approved for implementation at the local Southwest Region level are as follows:

(a) recruitment of a permanent professional computer specialist (GS-11/12 level) with qualified experience and expertise in UNIX, ORACLE, X-Windows, and TCP/IP. The specialist's immediate

responsibilities are to manage and maintain the networked UNIX-based ORACLE server, provide training/consulting for the in-house staff, and advise/assist the data management staff in the redesign of their data bases and the conversion of priority applications for the IT-95 platform.

(b) procurement of multi-user licensed ORACLE software for installation on the networked workstation.

(c) procurement of a UNIX workstation that meets the IT-95 functional requirements supporting open systems, to be networked as an ORACLE server. The funding for ORACLE and the workstation is a one-time outlay of funds to be limited to $40,000.

The La Jolla, Honolulu, and Monterey Laboratories are procuring a SUN SPARC 10 workstation to be implemented as the ORACLE server for their sites. The ORACLE software under procurement will be licensed for eight named users. Included in the ORACLE order for each site is a one-user license for a PC-based Computer Based Training (CBT) software. The CBT will be installed on a PC for access by the staff. With an ORACLE Education Center located in San Diego, California, formal training sessions will be provided to selected staff. (D. Roll, [619] 546-7057)

Information Technology Services Represented on Antarctic Cruise

Information Technology Services' Computer Specialist Rob Bistodeau participated in Leg I of the Antarctic Ecosystem Research Group's (AERG) 1993 Antarctic Marine Living Resources field research program. Bistodeau worked with AERG's Chief Rennie Holt and Ocean Acoustics Engineer Dave Demer to conduct a hydroacoustic survey in the area around Elephant Island. The data were collected, stored, and processed on a SUN Workstation. Bistodeau worked on the setup, maintenance, and monitoring of the hydroacoustic system during the 30-day leg. (R. Bistodeau, [619] 546-7055)

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Coan, A. L., Jr., K. E. Wallace, and A. R. Jackson. 1992. Differences in dolphin mortality rates in night and day sets for the U.S. eastern tropical Pacific tuna purse seine fishery. Mar. Fish. Rev. 54(2):7-14.

Because dolphins sometimes travel with yellowfin tuna, *Thunnus albacares*, in the eastern tropical Pacific (ETP), purse seiners use the dolphins to locate and capture tuna schools. During the process of setting the purse-seine nets, dolphins often become entangled and drown before they can be released. Data for the U.S. purse-seine fleet in the ETP during 1979-1988 show that dolphin mortality rates in sets made during the night are higher than mortality rates in sets made during the day. Even with efforts to reduce night-set mortality rates through the use of high-intensity floodlights, night-set mortality rates remain higher. The data are also used to simulate a regulation on the fishery aimed at eliminating night sets and show that dolphin mortality rates would decrease.

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Dickerson, T. L., B. J. Macewicz, and J. R. Hunter. 1992. Spawning frequency and batch fecundity of chub mackerel, *Scomber japonicus*, during 1985. Calif. Coop. Oceanic Fish. Invest. Rep. 33:130-140.

The average female *Scomber japonicus* collected from April through July of 1985 spawned 8.8 times during the 101-day sampling period. The average interval between spawns was 1.3 days in 32 females with more than one spawning stage in their ovaries. The average batch fecundity was 68,400 oocytes, or 168 oocytes per gram female wet weight (without ovary).

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Lo, N. C., L. D. Jacobson, and J. L. Squire, Jr. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49(12):2515-2526.

Fish spotters are pilots in small aircraft employed by commercial fishermen to locate, identify, estimate the size of, and direct boats toward pelagic fish schools. Data describing species, location, and size of schools can be inexpensively obtained from fish spotters but are difficult to interpret statistically. Lo, Jacobson, and Squire developed an index of relative abundance from fish spotter data based on extended delta-lognormal models and applied the method to data for northern anchovy, *Engraulis mordax*. In contrast with previous approaches, this method used all available data, provided an index for northern anchovy that was propor-

tional to abundance, and explicitly modeled factors (pilots, region, seasons, and time of data) that affected observations by fish spotters. Lo, Jacobson, and Squire also included information about mixed layer depth and sea surface temperature in models for a reduced study area and found that environmental data, where available, can be used to improve estimates of relative abundance from fish spotter data. Simulation results indicated that this approach is a cost-effective way to improve biomass estimates for pelagic species like northern anchovy.

Martin, A. P., R. Humphreys, and S. R. Palumbi. 1992. Population genetic structure of the armorhead, *Pseudopentaceros wheeleri*, in the North Pacific Ocean: application of the polymerase chain reaction to fisheries problems. Can. J. Fish. Aquat. Sci. 49:2386-2391.

Armorhead, *Pseudopentaceros wheeleri*, occur in the subarctic, epipelagic habitats of the northern Pacific Ocean and are known to reproduce on seamounts in the central Pacific. Over the last few decades, overexploitation of seamount populations led to dramatic declines in abundance of reproductive populations. Martin, Humphreys, and Palumbi undertook a study of the population genetics of armorhead to test whether distinct stocks exist in association with specific seamounts. They used the polymerase chain reaction (PCR) and a combination of DNA sequencing and restriction fragment length polymorphism (RFLP) analysis to analyze mtDNA variants for individuals collected from three localities: two seamounts and from the open ocean. They discovered that mtDNA haplotypes are not partitioned geographically, refuting the hypothesis that different seamounts harbor genetically distinct populations. Furthermore, genetic similarity of seamount and open-ocean fish supports the hypothesis that armorhead migrate between the central and northern Pacific Ocean for reproduction and feeding, respectively.

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Pacific rockfish were sampled from Cordell Bank, off central California, from 1985 to 1990. Hyperplastic and neoplastic lesions, involving dermal chromatophores, were observed in five species: yellowtail rockfish, *Sebastes flavidus*; bocaccio, *S. paucispinis*; olive rockfish, *S. serranoides*; widow rockfish, *S. entomelas*; and chilipepper rockfish, *S. goodei*. Yearly prevalences were highest, but static, in *S. paucispinis*, while prevalences in *S. flavidus* have risen steadily. The majority of lesions were black, but white, red, orange, yellow, and mixed color variants were also seen. Lesions were found in skin, fins, lips gingiva, tongue, urogenital papilla, and in the conjunctiva and cornea of the eye. Flat lesions were consistent with either melanophore (black), erythrophore (red), or xanthophore (yellow) hyperplasia. Neoplastic lesions included melanophoromas, melanotic melanophoromas, xanthophoromas, erythrophoromas, and mixed chromatophoromas. Electron microscopy did not reveal the presence of viruses and etiology of the lesions has not been determined.

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Approved by Science and Research Director, SWR

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